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ABSTRACT

The superordinate problem that the Threshold Project addressed is the nature of the language and learning difficulties that South African Standard 3 (Std 3) children experience when they change from their mother tongue to English as a medium for instruction. The primary focus of the Threshold Project work in 1987 was on a section of the South African Std 3 general science syllabus entitled plant structure, growth, and reproduction. As an aid to curriculum construction, this relatively non-technical report describes learning theories, reviews the educational research, and reports the results of pre and posttests to assess content knowledge and science process skills. Some of the major conclusions of the report are summarized as follows: (1) Research in the field of alternate conceptions in the South African context needs to be done; (2) a teacher-centered enquiry approach or transition model is the recommended form of instruction; (3) students whose native language was Setswana and were taught in the conventional way in English demonstrated no real learning gains; (4) students taught in a traditional manner in Setswana demonstrated large learning gains and (5) after being taught in the "transitional way" in English, students were able to demonstrate some learning gains. It was concluded that the policy of effecting a complete transition to English in Std 3 is hindering the learning of the children. (PR)

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Standard Three General
Science Research
1987 — 1988

Standard Three General Science Research 1987 — 1988

C.A. Macdonald

Human Sciences Research Council
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PREFACE

The Threshold Project had its beginnings in a pilot project that was conducted in the Institute for Research into Language and the Arts in 1985. It emerged from this early research that black children are experiencing difficulties with the change of medium of instruction in their fifth year of schooling. At first glance it may have seemed that these difficulties arise purely as a result of ineffective language teaching methods. However, the complex nexus of factors that constitutes black primary education required a closer look at different aspects of the total teaching-learning situation.

The Anglo-American and De Beer's Chairman's Educational Trust Fund agreed to provide funding to the Institute for the Study of English in Africa to commission the Institute for Research into Language and the Arts to undertake a three-year project on the problems which had been identified. The research was undertaken under the project leadership of Dr C.A. Macdonald of the Division of Sociolinguistic and Psycholinguistic Research.

In the course of the project a broad range of tasks was covered, including language testing, cognitive developmental research, materials development and classroom practices. The results of the research are contained in five final reports and a main report which attempt to contextualise the understandings reached in the larger social situation in which the research was located; there was also a serious endeavour to locate the research in the context of state of the art thinking in specific aspects of education, language teaching and testing theory, and cross-cultural cognitive developmental research. The intention behind this broad endeavour is to open up questions of educational theory and practice for further discussion and research on an academic level, and also to provide a knowledge base for serious thinking on developmental issues in the rapidly changing situation in Southern Africa.

The HSRC expresses its sincere appreciation to the Chairman's Fund for its funding of such a seminal project, and to the Institute for the Study of English in Africa for the invaluable part which its representatives played on the advisory committee of the project.

A final word of appreciation goes to Dr Carol Macdonald for the important role that she played throughout in the planning, conducting and completion of this groundbreaking project; also to Dr Rose Morris under whose aegis the major part of the project was conducted.

K.P. PRINSLOO
EXECUTIVE DIRECTOR: IRLA

November 1989.

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I should like to thank my co-workers on the Threshold Project, Helma van Rooyen, Angela Letsholo and Graham Walker without whose help neither the materials nor the research could have been produced. I should also like to thank the Bophuthatswana Department of Education, and in particular the Moretele Circuit, Norah Lebethe who smoothed our path to work in Lefofa, St Camillus, Selang and Seroto schools. Our thanks are also due to the principals and science teachers from these schools. We are also very grateful to Sister Austin and her staff at St Catherine's School, Florida, who have made me feel very welcome in their school since the winter of 1984. I am very grateful to Elizabeth Burroughs, who has been informally linked with our project, and came in on the second phase of the empirical work. Her sensitive insights are revealed in her analysis of the materials themselves and of the classroom transcripts, as well as in sample alternative materials that she produced.

Finally, I should also like to thank Vijay Reddy and Alan Kenyon who read the original manuscript and made suggestions for various improvements.

Carol Macdonald

ABSTRACT

The primary focus of the Threshold Project work in 1987 and to a lesser degree in 1988 was on a section of Std 3 general science entitled plant structure, growth and reproduction. We were able to integrate the investigation of a number of seminal project objectives in this work: firstly, we could develop a "transitional" model in relation to the one currently in use; secondly, we could develop sample curriculum materials for use in schools; thirdly, we could gather data on classroom interaction patterns, and fourthly, we could test process thinking skills in relation to the science curriculum.

We looked at three lines of research: firstly, the relationship between the learning of science and certain aspects of cognitive developmental theory; secondly, recent research and theorising coming indirectly from information processing theory (the concepts of information processing capacity, and metacognition or executive control), and thirdly, science educational research on alternative or intuitive conceptions of science concepts. All three lines of research have specific implications for primary science learning in our situation, but it is suggested in particular that we initiate further local research on alternative conceptions.

It has been a central contention in the project that the teacher's view of learning and knowledge determines what happens in the classroom and profoundly constrains what becomes available to be learned. In Std 3, the teacher uses a rote receptive model of teaching, in order, it seems, to try to balance the language and conceptual demands of the curriculum with how she sees children ought to learn. The project has developed a transitional model which tries to balance the propensities of the teacher with the needs of the child.

A set of specimen materials comprising 24 lessons on the plant was developed by the project team; in-service training was given on the use of these materials, and in-depth monitoring of their use in the classroom was conducted. A small-scale quantitative analysis was undertaken of patterns of interaction, and this was supplemented with insights from a qualitative analysis of classroom transcripts. It was found that teachers did not blindly follow the dictates of the material, but rather interpreted the materials in their own way; culturally-consonant ways of interaction were also maintained. This finding suggests that there may be stringent limitations on the effects of a purely materials-driven innovation.

Extensive testing of the effects of the materials on the pupils was also undertaken. From a rather simple research design we could deduce the way in which learning through English was preventing children from achieving their fullest learning potential; however, since English must be used, we were glad to report some modest learning gains with the use of the project experimental materials. We also found that children were able to demonstrate considerable facility with science process skills in an individual testing situation in the mother tongue. Their fluency in this situation stands in marked contrast with their inarticulateness and

passivity in the classroom (particularly at the Std. 3 level, where the new medium and the high concentration of new concepts makes considerable demands on them).

This relatively non-technical report may usefully be read in conjunction with the project main report which addresses central issues to do with the child's English language skills, typical school-based learning experiences, and the child's reasoning skills in relation to the demands of the curriculum, which itself is evaluated. The arguments are to be found in the main report of the project.

EKSERP

Die primêre fokus van die werk in die Threshold-projek in 1987, en in 'n mindere mate in 1988, was gerig op 'n afdeling van Algemene Wetenskap vir st. 3 wat as plantstruktuur, -groei en -reproduksie bekend staan. Die ondersoek van 'n aantal gedagteryke projekdoelwitte kon in hierdie werk integreer word: eerstens is 'n "oorgangsmodel" ontwikkel ten aansien van die een wat tans in gebruik is; tweedens is die stof vir 'n voorbeeldkurrikulum vir gebruik in skole ontwikkel; derdens is gegewens oor klaskamerinteraksiepatrone ingewin, en vierdens is prosesdenkvaardighede ten aansien van die wetenskapkurrikulum getoets.

Drie navorsingsrigtings is ondersoek: eerstens, die verband tussen die aanleer van wetenskap en sekere aspekte van kognitiewe ontwikkelingsteorie; tweedens, onlangse navorsing en teoretisering wat onregstreeks spruit uit inligtingsverwerkingsteorie (die konsepte van inligtingsverwerkingsvermoë, en metakognisie of uitvoerende beheer) en derdens, wetenskapsopvoedkunde-navorsing oor alternatiewe of intuïtiewe konsipiëring van wetenskapkonsepte. Al drie navorsingsrigtings hou spesifieke implikasies in vir die primêre leer van wetenskap in ons omstandighede, maar daar word spesifiek aan die hand gedoen dat verdere plaaslike navorsing oor alternatiewe konsepte gedoen word.

Dit was 'n sentrale aanname in die projek dat die onderwyser se siening van leer en kennis bepaal wat in die klaskamer gebeur en grondige beperkings plaas op wat beskikbaar gestel word om geleer te word. In standerd drie gebruik die onderwyser 'n drill-ontvanklike onderrigmodel, oënskynlik om te probeer om die taal en konseptuele eise van die kurrikulum te balanseer met hoe hy meen kinders behoort te leer. Die projek het 'n oorgangsmodel ontwikkel wat probeer om die ewewig te behou tussen die voorkeure van die onderwyser en die behoeftes van die kind.

Die projekspan het as 'n voorbeeld 'n stel van 24 lesse oor die plant ontwikkel; indiensopleiding oor die gebruik van hierdie stof aangebied, en 'n dieptemonitering van hul gebruik in die klaskamer uitgevoer. 'n Kleinskaalse kwantitatiewe ontleding van interaksiepatrone is uitgevoer, en dit is aangevul deur insigte van 'n kwalitatiewe ontleding van klaskamertranskripsies. Daar is gevind dat onderwysers nie blindweg die voorskrifte van die materiaal gevolg het nie, maar dat hulle eerder die materiaal op hul eie manier vertolk het; kultureelpaslike interaksiewyses is ook in stand gehou. Hierdie bevinding suggereer dat daar streng beperkings kan wees op die uitwerking van vernuwing wat alleenlik op stof steun.

Die uitwerking van die stof op die leerlinge is ook uitvoerig getoets. 'n Taamlik eenvoudige navorsingsontwerp het getoon hoe die feit dat die kinders deur medium van Engels leer hulle daarvan weerhou om hul volste leerpotensiaal te verwesenlik; aangesien Engels egter gebruik moet word, was die projekspan bly dat hulle enkele beskeie leerwinste met die gebruik van die eksperimentele projekstof kon meld. Die span het ook gevind dat kinders in 'n individuele toetssituasie in die moedertaal nogal gemaklik wetenskapprosesvaardighede aan die dag gelê het. Hul

vlotheid in hierdie situasies was in opvallende teenstelling met hul swak uitdrukkingsvermoë en passiwiteit in die klaskamer (veral op st. 3-vlak, waar die nuwe medium en die hoë konsentrasie van nuwe konsepte aansienlike eise aan hulle stel).

Hierdie betreklik nie-tegniese verslag kan nuttig saamgelees word met die hoofverslag van die projek waarin sentrale aangeleenthede aangespreek word wat in verband staan met die kind se taalvaardighede in Engels, tipiese skoolgebaseerde leerervarings, en redeneervaardighede in verhouding tot die eise van die leerplan, wat self geëvalueer word. Die betoë word in die hoofverslag van die projek vervat.

Since primary science is relatively young, there is no great volume of research and tradition of scholarship in this area as there is for secondary science education. This neglect is a pity, since the first eight years of school are not only in quantity a highly significant proportion of children's education (in many countries of the world it constitutes all the education of the majority of the children) but these years have perhaps even greater significance in occupying the formative period when a foundation of basic skills, concepts and attitudes is created.

Wyn Harlen 1985

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CHAPTER ONE

INTRODUCTION

The superordinate problem that the Threshold Project addressed itself to is the nature of the language and learning difficulties that Std 3 children experience when they change from the mother tongue to English as a medium of instruction.

We were concerned to conceptualise our research in a way that would facilitate the design of coherent and constructive strategies for change. It was felt that this would be best achieved by focussing on five interrelated factors, viz. the linguistic difficulties experienced by the children, thinking styles which might be culture specific, problems with content subject textbooks, disparities between English learned as a subject and English as required for its use as a medium; and finally, school based learning experiences. These factors were formulated into five main objectives, which became the foci of organisation for the Threshold Project. The objectives are as follows:

1. To establish the nature and extent of the linguistic abilities of Black pupils in Std 2-3. The corresponding final report is called *English Language Skills Evaluation*.

2. To establish in some detail the nature and extent of pupils' cognitive capacities using a model of natural thought which has implications for curriculum design. The corresponding final report is called *Reasoning Skills and the Curriculum*.

3. To develop a description of the present expectations of syllabus makers and textbook writers regarding the competence in English of children in Std 3 who are beginning to learn their subjects through the medium of English, and to relate such a description to the content of two lower-primary English courses in such a way as to illuminate possible disparities between the English and content-subject courses. The corresponding final report is called *The Disparities between English as a subject and English as the medium of learning*.

4. To establish the contribution of school-based learning experiences to the present lack of abilities of children in Std 3. The corresponding final report is entitled *School-Based Learning Experiences*.

5. To produce guidelines or principles intended to inform syllabus makers and curriculum developers. The corresponding final report is entitled the *Consolidated Main Report* which also makes reference to the previously mentioned four final reports, along with the present one.

The present report indirectly addresses *all five* aims of the project, in some modest way, since the research attempted to be holistic integrated research.

The primary focus of project work in 1987 and a secondary focus in 1988 was on a section of Std 3 general science entitled plant structure, growth and reproduction. It was planned to integrate our work around this section:

* firstly, we would develop a transitional model in relation to the traditional one;
* secondly, we would develop sample curriculum materials for use in schools;
* thirdly, we would gather more data than is currently extant in South African literature on classroom interaction patterns
* fourthly, we would appraise learning opportunities co-produced by teacher, pupils and textbooks (what has been called uptake), and
* fifthly, we would test an aspect of thinking skills in relation to the science curriculum.

It was decided that we would work in two phases. In each, certain measures would be taken before, during and after the teaching of the section on plants. These measures included interview data, classroom observation of the use of materials and interaction, and pre- and post-tests on vocabulary and concept development. In Phase One the teacher selected to teach would use the Primary Education Upgrading Project (PEUP) textbook Tsa Rona. In Phase Two he would be trained on and use materials designed by the project. It turned out that the teacher was not suitable for continued in-school research (because he was fresh from training college and understandably anxious in the classroom), and so Phase Two was rescheduled for the first quarter of 1988, with three other teachers. However the altered plans enabled us to conduct what we called Phase One A, in which the teacher taught exclusively in Setswana, and valuable bilingual data was gained hereby (cf. Chapter 6.1. below).

The science work will be discussed under the following headings:

2. Science learning and cognitive development.
3. Science teaching method and the transitional model.
4. The observation of classroom interaction patterns.
5. The appraisal of learning opportunities.
6. The Concept Test: 1987 and 1988.
7. The Science Process Skills Test.
8. The development and evaluation of new materials.
9. Proposals for further research and development.

This report is complemented by the science materials themselves, (including both a Pupil's and Teacher's Book), which are available together with a commentary on them which was prepared by Burroughs (1989).

CHAPTER TWO

SCIENCE LEARNING AND COGNITIVE DEVELOPMENT

In the past three decades there has been a developing interest in the relationship between learning science and associated cognitive development. It seems that the impetus for this was given by a growing interest in the work of Jean Piaget, who developed a complex but elegant theory on the development of logical or scientific thought. However there is now a growing impetus from another direction - the information explosion. There has been a proliferation of scientific information. For example, Chemical Abstracts took 32 years to report the first one million abstracts, and two years for the next million. The implication of this is that learners must address issues of knowledge acquisition, knowledge organisation, and problem solving, rather than simply the acquisition of "facts". Linn (1986) reports that the new basics for mathematics, science and technology include communication and higher problem solving skills and scientific and technological literacy - the thinking skills that allow us to understand the technological world around us.

Interest in the problems of science learning has led to the development of a new field - the science of science education. This field has drawn particular ideas from psychological research, particularly in cognition. Three domains in cognitive theory have proved to be useful tools for science teaching and learning, namely, processing capacity, problem solving (particularly metacognition), and intuitive or alternative conceptions.

To start with *information processing capacity*. There is an interaction between the number of chunks and the time required to memorise a chunk. The number of information processing chunks (meaningfully coded units) that can be processed adequately is a function of age and level of cognitive development (cf. for example Pascual-Leone 1970). It seems that learners reformulate their instructional materials which exceed their processing capacities in ways which might lead to misconceptions. There is research, for example, on the relationship between age and the ability to control a number of variables (Scardamalia, 1977) - this would have implications for trying to teach young children how to control variables in an experiment.

Cross-cultural research conducted in rural Natal by Juckes (1987) using a neo-Piagetian model of cognitive development has led to some interesting findings. This research was undertaken with Pascual-Leone's Theory of Constructive Operators which models cognitive functioning as a two level system of content-specific schemes and situation-free silent operators. Pascual-Leone distinguishes between cognitive competence or mental capacity (structural M), from learning (L structuring) which is dependent upon environment. The M-construct is a reserve of mental attentional energy that can be applied to task relevant schemes. Juckes used a classic task to establish the amount of M-power that subjects employed in a given task (functional M, or M(f)), as well as the efficiency with which they used this M(f). The data was analysed in terms of the first look, which gives an estimate of M(f), and repeated looks, which estimates the number of attending acts made over the task.

The results showed that eleven- and thirteen-year old children's arousal executives were increasingly poor, i.e. the eleven-year olds brought one unit less and the thirteen-year olds two units less than their available M to the task. In other words they were not using the information processing capacity which can be attributed to them. The 11 year olds only employed an executive capable of bringing 4, instead of the predicted 5, units of M energy to the task, and 13 year olds only used 4 from the expected (potential) 6 units. The maximum M value of e+4 found in Juckes' sample corresponds to the end of Piaget's concrete operational period. In different terms then, we could assume that these Zulu children were not progressing from concrete to formal operations, a common finding in cross-cultural cognitive research (Dasen, 1977).

However, Pascual-Leone's analysis allows for the possibility of developmental change, if the child is placed in demanding situations which can only be solved using formal operational reasoning. He contends that children can learn the appropriate reasoning skills (executives) with practice. For Pascuale-Leone, M-growth is maturational, and therefore M-power *is* available. Change can be brought about if "suitable mediated affective goals are 'planted' in the child by the educator" (Pascuale-Leone et al, (1978), p. 264). Pascual-Leone's notion appears to be compatible with Vygotsky's (1978) concept of mediation in the Zone of Proximal Development. Here, mediators (the mother, teacher, or more able peer) guide children to solve problems beyond their present level of independent functioning. It is important that teachers are mediators rather than transmitters of information in order that their children become active, independent problem-discoverers of the world. For Pascual-Leone, the aim of training is not to induce "learning" per se, but to encourage the long-term advantage of versatile executive learning.

It is important to note that what role the teacher adopts will affect the cognitive developmental style of her pupils. This issue will be dealt with again in the section below on method.

Other research has shown that the aspect of cognition that is most sensitive to cultural mediation is precisely in the field of *executive strategies* (Verster, 1986). Hence this is something which will have to be examined further in cross-cultural educational research and development. (Indeed the matter of metacognition is addressed at length in the Reasoning Skills Final Report.)

The concept metacognition has become increasingly popular over the last decade, and in many cases it has become "fuzzy" - covering too many, possibly distinct, attributions. To restrict ourselves to the most orthodox meanings will give a clear sense of direction, and here it is safe to follow Flavell (1976, 1979, 1981), who was one of the originators of the term. Firstly, metacognition is essentially cognition about cognition. Insofar as cognition involves perception, understanding, remembering, etc., so metacognition would be the superordinate term for "metaperception", "metacomprehension", "metamemory" and the rest. Metacognition can be differentiated into metacognitive knowledge and metacognitive experience, and one can distinguish between metacognitive and cognitive strategies.

Metacognitive *knowledge* is relatively stable knowledge, usually information about cognition (Baker and Brown, 1984). This knowledge is about *ourselves*, the *tasks* we face, and the *strategies* which we employ. We know about ourselves, such things as about what kinds of tasks we find difficult, and what kind everyone finds difficult. About tasks, we may know something about their relative difficulty (e.g. it is more difficult to read one's science book, than one's English reader). About strategies, we may know something like the following: verbal rehearsal and elaboration of material assists in retrieval (this is a technical version of meaningful rote memorisation!) It seems as though children will learn to acquire information of this kind through the abstraction of regularities in their cognitive processing over time (Flavell and Wellman, 1977), although it is very possible that they will learn it through the culture of the school. However, we do not know what our pupils know about strategies; for example they may well not know that interacting with objects does help one to recall their characteristics better. Their teachers may well not know this either.

One can of course use information about persons, tasks and strategies simultaneously. Flavell (1985) would claim that metacognitive knowledge is not different from other knowledge such as we have say, that we have about elephants or jackals (although it is of course, more interesting, since it is about that object of enduring interest, ourselves!)

Metacognitive knowledge serves as a base for metacognitive experiences. In other words, one may realise that one is able to perform a specific type of task (for example, rote learning facts to fill in in blank-filling exercises), and one may choose to use a series of mnemonics to facilitate the process. Metacognitive experiences often occur when cognitions fail. For example, although the child may not think explicitly "I do not understand", a sense of confusion may lead him to try a different strategy. An unsatisfactory condition is undetected cognitive failure; this is where one does not know that one does not know. Apparently this is a pervasive problem in comprehension monitoring (Garner, 1987 cites four reviews). In our Reasong Skills Final Report, we discuss the work of Markman (1977, 1979, 1981, 1985) who has come up with surprising findings on the widespread failure of young children to monitor their comprehension: this work points to a need for a reappraisal of what one can expect from young children at junior primary to senior primary phase.

However, perception of cognitive failure may lead to strategy use. The actual use of strategies involves cognition, whereas the monitoring of these strategies involves metacognition. For example, one may jot down all the facts one has memorised, and then refer back to the book and check the accuracy of recall; one may then decide that further rehearsal is necessary. It is clear that there are two components in the use of strategies - the skills themselves and also the motivation to use them. Obviously both factors will vary across learners. It seems clear from the literature that young children may find strategies difficult to use, as they intrude unduly on mental space that children are using for cognition <u>per se</u>. (We discuss this aspect further in reviewing the work of Bereiter and Scardamalia (1985 and elsewhere) in the Reasoning Skills Final Report.)

In the information processing literature, there is an emphasis on *executive control*, which roughly speaking, approximates to the interrelations between metacognitive experiences and strategy use. So, on the one hand, one might talk about fostering introspection and metacognitive experiences, and on the other hand one could talk of "self-control" training.

If a child were to decide to investigate some interesting physical phenomenon (for example, why coins sink, but bits of wood don't), the child could design some experiments, evaluate the results and try to work out a plausible explanation for this. In information processing terms, the full blown explanation for his actions might be as follows (cf. Sternberg, 1981):

(a) deciding on the nature of the problem ("the heavy thing sinks, perhaps we should try other heavy things too")
(b) deciding on performance components relevant for solving the task ("we need different objects, water, and a bucket")
(c) deciding on how strategically to combine performance components ("we should throw these things into the bucket one at a time and time how long they take to sink, or see if they float")
(d) monitoring solution processes ("well, the horse-shoe sank, and so did the shoe, but the empty glass didn't, and neither did the plastic jug")
(e) being sensitive to external feedback ("perhaps it has to do with what the object is made of, and not with the weight")

An important feature of executive routines is that they can be taught. However, it has been found that that it is difficult to teach students metareasoning skills which they can transfer to new knowledge; strategies seem to be closely bound to subject matter knowledge (Linn, ibid). The instructional implication of this is that the teacher should provide numerous instructional experiences in a variety of domains and continuously point out the metareasoning strategies that have been employed. It is obviously important to children that they should see these activities as being reasonable and workable, and that they have a counterpart in real-life experiences.

The fact that one can (in theory, at least) teach metacognition or executive control has been capitalised on in the new thinking programmes developed in Great Britain and the United States (e.g. de Bono's CoRT). The inclusion of thinking programmes to help across-the-curriculum learning has been integrated into the Upttrail Trust project (van der Vyver, pers. comm., 1989) for Std 3, but the results of this innovation are not yet available: their experiment is due to take place during the course of the 1989 school year. Teaching that links real-life experience to more science-based activities would seem to be a valuable alternative to current content based syllabi, but such a re-orientation would involve specific training for teachers, who are not familiar with this approach.

The findings of the Threshold research on cognition indicate that there are cross-cultural differences in metacognition which are likely to have repercussions on school learning (cf. Macdonald, 1987). However, the explicit implications can only be worked out analytically at present. In our work on cross-cultural development we have focussed not so much on

cultural differences, but on the need to analyse the nature of the task that the child has to engage in, and what mediation is required to bring him closer to becoming an autonomous problem solver. In our analysis of the demands of using English as a medium of instruction we have come across exciting work (cf. O'Malley, 1988) that purports to integrate language and content learning through the use of cognitive and metacognitive strategies. (For further details see Chapter Seven of the English Language Skills Evaluation Report.)

A second area of research that has been burgeoning has been that on alternative or *intuitive conceptions*. Intuitive conceptions can be held by adults as well as children. Reasoners (and here we would be particularly interested in young children) construct views of natural phenomena from present experience guided by analogical reasoning. Factors affecting intuitive conceptions include process-capacity limitations, the availability of alternatives, and lack of prerequisite knowledge.

Interestingly the conceptions held about a given topic such as electricity generally fall into a few categories (Cohen, Elyon and Ganiel, 1983) and occur consistently in studies of different age respondents (Driver, 1983). For example, Linn (1983) found that children and adults both think that a steel cube will displace more volume than an aluminium cube. They form this notion by analogy with the insight that velocity is affected by weight, so therefore wrongly infer that displacement is also affected by weight.

One small example of alternative conceptions that we found in our research was that the seed leaves of the bean plant grow rather than wither with age. This interpretation is drawn falsely from the generally true observation that things increase with size when they grow. (In fact the rest of the bean plant grows bigger while the seed leaves or cotyledons shrink, so the children have to make a co-ordination of the two pieces of information.) We do not know what intuitive conceptions Std 3 pupils have about the subject matter they have to learn in physical science, for example, and this would be valuable information, given the fact that we know that children might integrate information given to them by their teachers and ideas they already have in unexpected ways. If the teacher has a good idea of what her children already believe, she can alter her input accordingly.

But intuitive conceptions may be more critical in the success of a curriculum than it would seem at first glance: they tend to resist change. Linn (1986) uses Lakatos' (1972) ideas from the philosophy of science to try to understand why this should be so. Lakatos makes a distinction between a hard core of ideas and the protective belt of ideas. The hard core of ideas in a subject are those that are unresponsive to data. In contrast, the protective belt of ideas are those which are readily changed to defend the hard core. The hard core of ideas can be followed as long as they predict novel information, even though they make false predictions.

An educational implication of this is that we need to know what metaknowledge the reasoner might use to test his ideas and what the critical mass of wrongly predicted events is that leads to a change in the hard core of ideas. A more serious immediate implication of the idea

of the resistance of alternative conceptions is that we cannnot assume that the presentation of clearly integrated, logically presented material will lead to reasoning changes. (1) The changes will come through a sensitive mediator, who presents the reasoner with additional options to their interpretation. This expansion to the notion of conventional mediation by the science teacher makes quite extraordinary demands in the classroom situation. Perhaps information about alternative conceptions should be derived from research and built into materials, so that each teacher does not have to investigate her pupils' conceptions in full. (2)

The literature (cf. for example, Linn, ibid) on instruction seems to suggest that we cannot easily get reasoners to change their minds through elaboration or contradiction. Rather it seems that a comprehensive strategy of cuing of solution strategies, combined with increasing the reasoner's metareasoning skills would be most likely to succeed. This comprehensive strategy would seem to be a far cry from the practice in science classrooms at present. Kenyon (pers. comm.) has pointed out that the implications of such a comprehensive strategy on classroom organisation would be enormous, and that one would have to examine the possiblities of vertical (ability) grouping of learners, and perhaps team teaching for teachers.

The most sophisticated writing on primary science (cf. Harlen 1985) does not make explicit the effects of alternative conceptions, although these are taken into account in the important process of matching the child's learning to his state of development. In order to understand the process of matching, we must take account both of the kinds of concepts that the child can deal with, as well as the process skills which he can use. The process skills which are appropriate for the child in the fifth year of primary school are observation, interpretation of information, raising questions, hypothesising, devising investigations, and communicating by making records, tabulating etc. (3) In section 7 below, we report a study on Std 3 children's capacity to carry out process skills inherent in our science module in their mother tongue.

Harlen's work has been deeply influenced by the classic results of Piagetian research in relation to what kind of scientific thought the child will be capable of at a particular stage. Hence, she claims that children of 7-9 years should have the following limitations (Harlen, op cit p.131):

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(1) This is an interesting limitation on the evaluation of science learning materials. We have to know what the children think before we can determine whether specific materials work.

(2) The notion of alternative conceptions is more acceptable as a constraining variable in learning from a generative view of learning, cf. section 3 below.

(3) In the development of our materials, we did not make use of these process skills to their fullest extent, partly because they demand a high level of language skill, and familiarity with a wide range of resources in child-centred learning situations. Also, work in physical science avails itself more readily of the full range of process skills than does biology.

- thought about whether changes have really happened or are only apparent depends on how strong the visual impression is; thus apparent changes in the volume of the same amount of liquid in different containers (which can confuse adults, after all) are less easily challenged by thought alone than changes where reasoning can more easily contradict perception;
- the quantities that can be manipulated in the mind are those that can be seen and easily represented mentally, such as length and area; mass, weight and temperature are less easily grasped, and
- as might be expected, the complexity of a problem or situation influences the ability of children to approach it using rational thinking; they may be able to investigate the effect of one variable but if there are two operating together it is unlikely that their effects can be separated.

The first limitation mentioned above is obviously derived from the Piagetian conception of the dominance of perception over conception at the stage of concrete operations. Similarly, in the second point, it is recommended that more abstract concepts should be avoided. The third point refers to the Piagetian notion of the developing notion of the co-ordination of two variables. However, what is said here is in no way contradicted by critics of Piaget (e.g. Donaldson, 1978) who claim that children are capable of much more than he gave them credit for; in other words, this is still part of the accepted orthodoxy about cognitive development.

In using the work of Harlen on the Threshold Project, we have drawn from her statements about 7-9 year olds rather than 9-11 year olds; firstly, because the syllabus looks at concepts within this range; and secondly, because this includes the fifth year of instruction in the British primary school (and therefore roughly equivalent to Std 3).

Two areas for research seem salient in relation to science learning and cognitive development. Firstly, it would be extremely valuable to find out in detail what alternative conceptions the black children have about elements of their general science syllabus, in order that these conceptions can be taken account of in teaching and learning materials. Alternative conceptions that arise as a result of language differences would be especially interesting, theoretically (in terms of the Sapir-Whorf hypothesis) as well as empirically.

Secondly, a second area of research that would be of interest before a full-scale promotion of a process approach in a new curriculum is that of the teachers' capacity to recognise, manipulate and teach these skills spontaneously. It is our impression, and also that of the Science Education Project (Hoodie, pers. comm. 1988), that teachers cannot readily identify process skills. If this impression is substantiated, then it would follow that process skill facilitation would have to be built into the materials, and this would lead to less flexibility for the teacher. Ultimately, the implementation of a full-blown process approach would require teachers that can spontaneously facilitate these skills in an only partly structured situation.

To further extend the implications for teacher education, we have focussed on a subtle but important notion in our English Language Skills and Reasoning Skills Final Reports, and that is the development of self-regulatory mechanisms for teachers (this ties up with metacognition): teaching teachers to use tools of self-regulation (for example, checking, planning, monitoring and revising) will lead them to develop their own cognitive repertoire and level. Getting them to go about their tasks differently will actually *induce* change, without there, at first, being a conscious awareness of the explicit rules of the task performance. This is a critical notion which may underly effective programmes for change.

CHAPTER THREE

SCIENCE TEACHING METHOD AND THE TRANSITIONAL MODEL.

In the Threshold Project Interim Report (Macdonald 1988 pp.33-39) there was some discussion about the nature of the primary children's school-based experiences. The differences between rote and generative learning has been much debated in the general educational, language education, and science education literature. In science educational terms, we can refer to rote versus generative learning (Harlen and Osborne, 1985), or direct instruction versus discovery learning.

It is the contention of Harlen and Osborne (ibid) that the teacher's view of learning and knowledge determines what happens in the classroom and profoundly constrains what becomes available to be learned. Our school system was orginally predicated on an encyclopaedic conception of knowledge, where knowledge is content which can be stored in books. With this conception came the tools - recitation, lectures, textbooks. Let us look for a moment at the four "tasks" of teaching (Westbury, 1973) and see how these are managed by the rote teacher.

The first task of teaching is the covering of a body of material (COVERAGE); the second is the engendering of mastery of this body of material by the pupils (MASTERY); the third is the creation of a positive learning climate (AFFECT); the fourth is the management of the class, which must work together in the interests of task attention and order (MANAGEMENT). (These four tasks of teaching are addressed at length in the School-based Learning Experiences Final Report, specifically in the context of junior primary education.)

The traditional rote teacher uses recitation, lectures and textbooks as a coping strategy: it facilitates coverage, leads perhaps to a nominal mastery of the facts, the teacher has control over the attention of the pupils, and secures their attention on task.

If a teacher runs an open, child-centred classroom, she will immediately be faced with challenges in all but the AFFECT tasks that face her. Class MANAGEMENT becomes a great deal more complicated with groups working at different paces, and perhaps on different tasks. It is difficult to be certain that pupils will COVER the full body of material that is prescribed for them, and if the teacher is not there to give continuous feedback, how will she be sure that the pupils have MASTERED the task at hand? Small wonder that it is difficult to sustain an open classroom with generative learning. Hoetker and Ahlbrand (1969) found that rote learning was still the norm over the course of fifty years while it was being decried by educators. Galton (1986 pers. comm.) found that there was little genuine negotiated learning in primary school classrooms, even when pupils were put into groups physically.

The urgent note in education theory about the importance of generative learning comes from a change of Western philosophy in the twentieth century. Westbury (op cit p.117) characterises this change as the "turning of the person into an act of knowing". There is now a higher priority on the question and the act of asking questions than there is on the bodies

of answers that we have to past questions. This is the import of Polanyi in epistemology, Kuhn in science, Piaget in psychology and Dewey in education. The constructivist orientation in thinking (i.e. the view that both perception and thought are contructed and not simply received) has not however been matched by technologies in the classroom: books, lectures etc, delivered bodies of facts, but what will deliver a questioning learner who has to be armed with the methods of asking new questions, and evaluating the answers? Mastery, coverage, management and affect all still have to be addressed. (The options for alternatives for western-style child-centredness are discussed at length in the reports on school experience, and on reasoning skills in the curriculum. There are clearly more possibilities than are suggested in the popular educational literature.)

Westbury argues that information that trains the teacher in educational aids like Dienes blocks or Cuisenaire Rods addressed the heart of the dilemma that the generative teacher faces; he cites Dienes (1959 pp 208-9):

> Let it immediately be understood that decentralisation does not mean chaos: nor does it mean any abrogation of the teacher's responsibility as regards the conduct of the class. The way this responsibility is discharged will, however, be different in a decentralised classroom from the way it is discharged in a centrally controlled one. The children must feel with certainty that the teacher is in charge of things, but at the same time he has arranged that information can reach children without his intervention. The children must also feel that they can check their own or other's work in an independent manner, and they will consult the teacher if some problem arises which they are unable to solve for themselves.

Dienes matched his intuitionist conception of mathematics with play- and game-like materials which are both self-instructing and self-managing. Is the same being sought in science education?

The generative notion in science teaching encourages pupils to work out scientific principles on their own. The radical version allows pupils to seek out not only solutions, but also problems on their own. Obviously, this method is very slow, for despite the fact that pupils are supposed to be enacting the very processes of scientific discovery, they may be going up the garden path of failed attempts and discouragement. The more honest approach (for who actually reinvents the wheel?) is the so-called guided discovery approach, in which pupils engage in discovery learning in areas in which they are most likely to encounter experiences which change their alternative conceptions and increase their understanding of scientific discovery.

If a guided discovery approach is used, learning situations can be set up that do not exceed the processing capacities of the pupils. However, guided discoveries may have no intrinsic interest to the pupil (cf. AFFECT above), but more seriously, Linn (1986) admits that procedures for directing pupils to gain useful insights are not well-established. These procedures would have to be able to counter the pupils' alternative conceptions, and also teach them cognitive and metacognitive strategies for

approaching problems. The development of such procedures is a relatively undeveloped area, and one which has not yet been explored in primary science education specifically.

It is our contention that while our teachers have been taught about discovery learning, when they deal with higher primary children, they are most unlikely to use this approach. An obvious obstacle in the way, is the use of the new language medium, which can hardly be used by the pupils, to explore concepts that are not yet in their repertoire. Also, the press of the syllabus, and the difficulty of many of the concepts lead teachers to the haven of receptive rote learning.

Although the surface manifestations of discovery learning are manifested in the child-centred lower primary classrooms, it is not clear that constructivism is part of the cultural epistemology of the Bophuthatswana teachers. We would argue that this philosophy is not part of the received knowledge of any body of teachers in the country, and that its importance is perceived by theoreticians and lecturers, but still to be passed to common consciousness. (Reddy, (pers. comm.) reports that in the United Kingdom consciousness is sufficiently raised to the level of looking at teacher training programmes that are compatible with the philsophy of constructivism.) Perhaps this change will come about with a new "technology" that allows the teachers to manage all four tasks of teaching to her satisfaction. Attitudes will change when the tools of effective behaviour are provided.

We worked with the assumption, based on previous research in Bophuthatswana and Soweto (Macdonald, 1983, 1984, 1985), that unless there is positive intervention, teachers will teach science using a teacher-centred, Rote-Rhythm method. In section 3.2 of the Interim Report of the project (Macdonald, 1988) this rote learning method was discussed, with its emphasis on memorisation and recall on the part of the children. The teacher's role was principally to give clear expositions of information, ensure the children's attention, and reward accurate recall.

The idiosyncratic aspects of the Rote-Rhythm Method would include at least the following: as the teacher is introducing new ideas and structures the children are cued or simply expected to repeat spontaneously the last word the teacher has used in his discourse turn; along a similar line, there is also an expectancy that the children will complete the teacher's discourse turn with the newly introduced item. The full impact of the method cannot be experienced without actually listening to a lesson; the chanting and sentence completion form a kind of choral ritual that appears to maintain a spirit of communality in the classroom.

The transitional model designed by the project focussed on the need of the children to develop their communicative as well as their process skills. The latter include observation, interpretation, inference, explanation etc. The learning experiences which should be provided for the children are: firstly, that pupils should work on tasks which are meaningful and purposive, developing the process skills of the child in practical or written work; secondly, the productive language skills of the pupils should be developed by tasks such as those described, where

the child develops the necessary vocabulary, grammatical structures and interaction skills. The transitional model is reproduced in full below.

Part of our conception of the transitional model has been to develop a relatively teacher-centred discovery- or inquiry-method. In other words, the teacher can still have visible control and be closely managing the class, but at the same time the children could be developing their process skills.

Some evidence for the viability of this approach comes from the work of Eggleston, Galton and Jones (1976) who cluster analysed a well-validated instrument (the Science Teaching Observation Schedule or STOS). Apart from a style they called Inquirer (which was pupil-centred and involved lots of practical work), and one called Informer (which involved non-practical rote learning), they also identified a third, called the Problem Solver. This style involves an orientation to science as a problem-solving activity, and the teacher challenges the children with a comprehensive array of questions. This is a teacher-centred inquiry approach which, although it has only been attested in the United Kingdom, Canada and Australia (Eggleston, 1980), might suit our classroom situation better than a fully-fledged pupil-centred one would. A similar pattern to the Problem Solver - the Discoverer - has been found by Hacker (1984) to predominate in primary science classrooms in Australia.

This discussion on teaching method leads naturally to the report on the classroom observations of interaction patterns produced with the use of the new materials we developed. It should be noted that questions about current method are taken up in detail in the two other related final project reports, Reasoning Skills and the Curriculum, and more specifically School-based Learning Experiences.

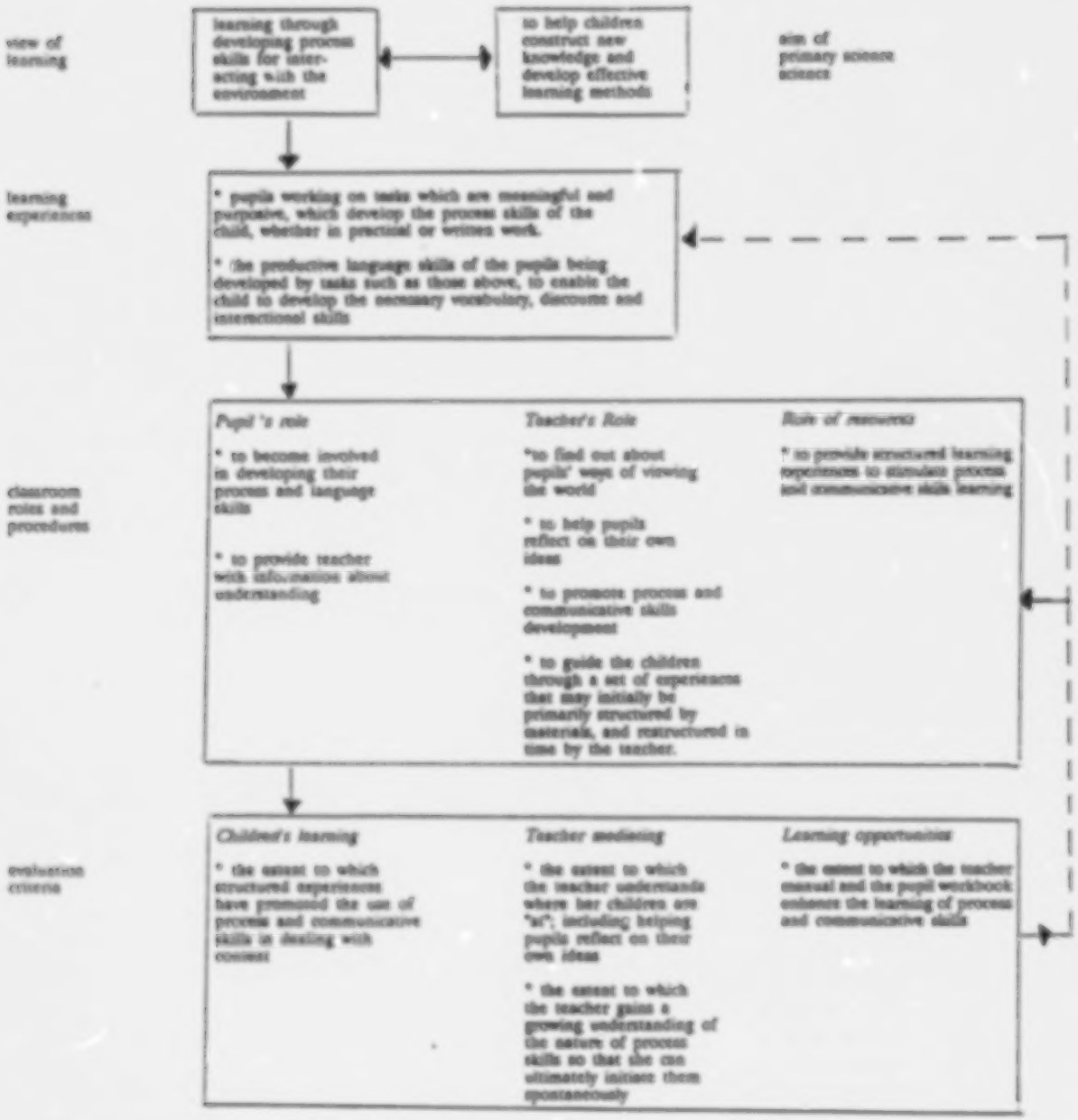
view of learning
learning through developing process skills for interacting with the environment
to help children construct new knowledge and develop effective learning methods
aim of primary science science
learning experiences
* pupils working on tasks which are meaningful and purposive, which develop the process skills of the child, whether in practical or written work.
* the productive language skills of the pupils being developed by tasks such as those above, to enable the child to develop the necessary vocabulary, discourse and interactional skills
classroom roles and procedures
Pupil 's role
* to become involved in developing their process and language skills
* to provide teacher with information about understanding
Teacher's Role
*to find out about pupils' ways of viewing the world
* to help pupils reflect on their own ideas
* to promote process and communicative skills development
* to guide the children through a set of experiences that may initially be primarily structured by materials, and restructured in time by the teacher.
Role of resources
* to provide structured learning experiences to stimulate process and communicative skills learning
evaluation criteria
Children's learning
* the extent to which structured experiences have promoted the use of process and communicative skills in dealing with content
Teacher mediating
* the extent to which the teacher understands where her children are "at", including helping pupils reflect on their own ideas
* the extent to which the teacher gains a growing understanding of the nature of process skills so that she can ultimately initiate them spontaneously
Learning opportunities
* the extent to which the teacher manual and the pupil workbook enhance the learning of process and communicative skills

Figure 3.1 *A transitional model for learning primary science* (Macdonald and Van Rooyen, 1987, adapted from two models in Harlen and Osborne, 1985)

CHAPTER FOUR

THE OBSERVATION OF CLASSROOM INTERACTION PATTERNS

Data about what happened in the classroom situation as the materials were being trialled was obtained from two sources. Firstly, there was quantitative data from a classroom interaction observation schedule, and secondly, there was qualitative data drawn from transcripts of the experimental lessons. The quantitative data was interpreted holistically by the present author, while specific additional interpretive statements made by Burroughs (1988) have also been added.

In anticipation of observing both the traditional and transitional models of primary science teaching, a matrix for the classroom observation of science teaching (COST) was drawn up. This matrix has two main sections, focussing on teacher-centred and process-thinking patterns respectively. A copy of the COST may be found in Addendum 1 at the end of the report.

It might be argued that the reliability of the results obtained in the COST experiment is difficult to assess because there was only one rater (the author). Ideally, video recordings should be made, but the practical, technical and financial implications of producing recordings which faithfully reflect the interactions the classrooms are not only very considerable but probably also insurmountable at present. On the other hand, the results can be claimed to have a good measure of internal consistency for the rater has used SEPTOS in approximately 50 classrooms previously.

One main source for the COST matrix categories was STOS (the Science Teaching Observation Schedule) mentioned in the section above. Although STOS was developed for the senior secondary school classroom it has been found to be largely suitable even for the primary classroom. STOS is predicated on the presupposition that even if there is a healthy emotional climate in the classroom, and good class management skills, these are necessary but not sufficient for effective learning, which is felt to be a function of the intellectual transactions in the classroom. (4)

STOS captures the use of teacher- versus enquiry-centred styles. For example, the teacher centred style is characterised by plenty of teacher statements of facts and principles and request of pupils to recall statements and principles. On the other hand, enquiry centred teaching would be characterised by pupils' involvement in group work and questions involving hypothesising and explanation.

The COST matrix includes all the basic STOS categories, as well as those added by M.A. Macdonald in the revision called SEPTOS (an instrument used for the evaluation of early Science Education Project work in Ciskei, 1976-1979). The extra categories were those that characterised

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(4) In relation to what we claimed in the previous section, on the four tasks of teaching, the focus of STOS is on the *processes* of COVERAGE and MASTERY.

part of the Rote-Rhythym method, i.e. chorus work, and even the incorrect dissemination of information.

Further categories were added which we anticipated would characterise a teacher-centred enquiry approach, i.e. the teacher actively soliciting the use of process skills from the pupils, including observation, inference, explanation etc. We characterised the distinction between rote and process learning by setting out the two kinds of behaviours in separate sections. However, it has to be admitted that statements of facts and principle will necesssarily be a component of both approaches.

In 1987 we did not gather any data on the style engendered by our new materials. However, four observations on our experimental teacher Thabo Manne, using the traditional textbook, Tsa Rona revealed that he used a rote method, but without the rhythm component. He spent the major proportion of his time making statements of facts or principle, and asking his pupils to recall these. The pupils were not very active, only making direct observations in one lesson, and otherwise answering questions their teacher asked them. However they tended to answer individually, and did not repeat as a group. A possible reason for this was that Thabo was fresh from training college in 1986, and perhaps the survival teaching mentioned by Hawes (1979) had not yet made an impact on him. Furthermore he teaches at a "model" school where the worst excesses of the Rote Rhythm method are likely to be strongly discouraged.

The COST matrix was used in three schools in Phase Two in 1988. (This did not include the one Phase One school worked with in 1987.) However, since in one of the schools the teacher was changed mid-way through the module, the results of only two teachers are reported. One teacher (Salome) was observed five times, and the other one (Eliah) four times, but it is felt that an explicit comparison of their performance on two lessons (a double period dealing with vegetative reproduction) would be the most productive. Other characteristic teaching behaviours will be dealt with in further discussion. One thing that did emerge was that the particular nature of the lessons in the materials which the teachers were following produced quite significant shifts in the interaction patterns of the lessons. In other words, a lesson involving a practical demonstration would generate different interaction to one involving a game. Overlaying this, however, were patterns idiosyncratic to the individual teachers.

The results of the observations of Lessons 7 & 8 (Another way to grow a plant) are shown overleaf in Figure 4.1. The figures represent percentages of the total possible time units that a behaviour occurred. For example, statements of fact or principle in each of 26 one-minute time units (47% of 57 minutes). Behaviour can only be indicated once within a one minute interval.

There are a number of observations that can be made from the simple data that is presented in the summary table (which contains only those categories that were observed). In general terms (especially when compared to other, differently planned lessons), the patterns revealed here are rather similar, although there are some differences worth commenting on.

BEHAVIOURS	% of possible units	
Teacher-Centred	Salome	Ellah
Teacher makes statement of fact or principle	46	40
Teacher asks pupils to recall fact or principle	18	23
Pupil recalls statement of fact or principle	9	21
Teacher uses Tswana for explanation	12	5
Teacher repeats statement	12	28
Task attention assured	26	17
Class drill answer	12	12
Teacher records accurate recall	--	4
Teacher corrects pupil answer	2	--
Teacher makes statement of problem	2	--
Teacher makes statement of experimental procedure	14	28
Teacher directs pupils to self-evident procedure	2	12
Pupils involved in self-evident procedure	7	18
PROCESS ORIENTED	% of possible units	
	Salome	Ellah
Teacher asks pupils for novel examples	--	2
Teacher asks pupils to make direct observations	12	16
Teacher asks pupils for interpretation	5	12
Teacher asks the pupils to make predictions	5	9
Teacher asks pupils to give explanations	--	2
Pupils use the senses to gather information	--	5
Pupils make inferences from observations or data	--	9
Pupils apply facts or principles to problem-solving	21	21
Pupils try to explain a phenomenon	--	5
PUPILS GROUP BEHAVIOUR		
Pupils talk about the task: Tswana	5	5
Pupils talk about the task: English	5	5

Figure 4.1: *COST results for two teachers on Lessons 7 & 8*

Salome was, for example, more likely to make sure that her pupils were paying attention to the task. It seems that this was perhaps necessary in a class who did not seem to show much intrinsic interest nor real comprehension. However, asking explicitly if people are paying atten-

tion, a characteristic of the Rote-Rhythm method, ("not so?" - "yes"), wastes time that could otherwise be spent on information or actions that would of themselves attract attention. Burroughs (1988) feels that this phatic link does not really serve as evidence that there is either full attention or comprehension.

Salome also used more Tswana than did Ellah, and when one looks closely at the lesson transcripts, one finds that Salome was more likely to give long explanations of entire concepts or method than did Ellah, who used Tswana more fleetingly, for phrases and vocabulary. Burroughs (ibid) notes that the use of Setswana increased when the recording equipment was removed. Her analysis of a number of transcripts led her to this conclusion:

> In general, the rule of thumb appears to be that Tswana is used when the teacher believes there to be a possibility of her idea, instructions etc. in English not being understood by the class. The use of Tswana may also be an index of when the teacher herself feels insecure about her ability to communicate. Certainly the fact that Tswana explanations are given quickly, fluently, and at rather greater length than English ones would seem to bear out such an interpretation.

Ellah tended to ask far more questions than did Salome, and hence her pupils often answered machine-gun recall questions. Ellah often repeated a statement that she had made, especially if she had just asked a child to answer a recall question. So the sequence would go : Statement-Question-Recall-Repeat Statement. The visual effect in the transcript (see below) is one of massive repetition of information. Burroughs (ibid) observes that even though Ellah seemed to give her children much more room than Salome to participate, this was within rather narrow parameters: the children are not given a chance to describe or interpret materials that they are working with.

Ellah, who is an experienced science teacher, also asked her children to perform more process skills than did Salome, who is a novice (science) teacher, and our interpretation of this is that Ellah was more competent on her subject matter understanding. She certainly was more au fait with performing experiments, and did this with greater confidence than Salome. It may be that this is a single example of a deeper level constraint that operates more generally within the domain of teacher development: the more confident the teacher is in her subject domain generally the more open she may be generally to innovations of method.

Although there was information built into the lessons - about the nature of reproduction cycles, and the method of making a cutting - the teachers transform the lesson by the repetition of information, and the frequent requests for recall. *It is quite clear that the materials themselves cannot completely control what the teachers do in the classroom. The teachers transform what they have been given by their own interpretation of the task itself, by their personal style, as well as by their perception of the needs of their pupils. This well-substantiated observation should serve as a cautionary tale for those who believe in materials-driven innovations.*

In specific terms, we found that teachers neither rewarded accurate recall, nor did they correct pupils' answers explicitly. Pupils were expected to infer the validity of an answer by the questioning process that followed. However, Ellah gave a rather idiosyncratic cue (which her pupils may be familiar with) to an incorrect answer - she would say "Is it?" with a high rising intonation, followed by further questions. It seems to be very important to the teacher that the children should understand what she is saying, rather than that she should understand what they are saying. The children seem to have to pay particular attention to rather minimal cues that their teachers give them: this phenomemon has been clearly attested in the work of Kok (1986), who sees this as one of the determining constraints of a problem-solving situation.

It should be pointed out that the COST category "pupils applying facts or principles to problem solving" was well represented solely because pupils were exercising their linguistic capabilities past their limits by trying to fill in a cloze text which described the method of making a cutting - an activity which they had just observed. (Further remarks are made in the commentary on the materials about these difficulties, and the possible solution of using c- rather than cloze-items (Burroughs, 1989)).

Although there was generally a similar pattern for the two teachers over the same lessons, it will be noted that more categories and a higher frequency are characteristic of Ellah. In fact, her class was run at a far faster pace than Salome's, which we interpreted as a personal factor, as well as a result of Salome teaching children with generally weaker competence. (5) Although it is difficult to quantify pace from our data, we can say that there were about three different intellectual transactions per minute in Ellah's class, and two in Salome's - perhaps Ellah's class could be said to be carried 50% faster than Salome's.

There is one behaviour prominently lacking in all our records, and that is *pupils asking questions*. Children neither ask questions for clarification nor for information. Yet asking questions is something which is characteristically associated with primary school children. Indeed Hinton (op cit) explicitly built this in as an addition to the classical form of STOS. She talks about the original contributions that young children characteristically make, and while they may appear to be off the subject, they offer a clue to the pupil's state of mind (cf. the discussion above on alternative conceptions), and often give rise to very fruitful learning experiences. While the children's limited English competence is possibly an important reason why they do not make contributions of this nature, it is our impression that spontaneous contributions are actively discouraged very early in the child's primary school career. This impression was confirmed in the ethnographic classroom study (School-Based Learning Experiences) conducted after the science research was complete. Other corroboration of the early inculcation of this passive, receptive role is given very clearly in the work of Kok

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(5) We see this as a function of the individual and group testing that we conducted with these pupils in English and the vernacular, as well as from their level of visible engagement in lessons.

(ibid): the sensitivity to the teacher's intentions, and the willingness to suppress the expression of one's own insights seem to be two sides of the same coin.

Numerical data, however comprehensive, does not give any feeling of the quality of the interaction. Nothing can demonstrate this as well as being in the classroom does, but in order to illustrate several of the points that have been made here, two excerpts from Ellah's lesson are reproduced below.

Ps Morning, Maam.

T Okay, sit down.

Ps Thank you, maam.

T Take out your work and your pencils.

T Keep quiet. Just take out your pencils and your workbooks. Please put away all those books. Only your workbook and your pencil must be on the table. Take them out quickly, man. Are you ready?

Ps Yes

T Mmatladi dira ka pele (Mmatladi be quick.) Open up on page 24. Page 24. Have you opened up?

Ps Yes

T Okay. Then we are going to learn about the other way of growing a plant. We have learned how to plant a seed and a bean, sorry a bean seed and a maize seed. So we are going to learn more about planting plants. So when we plant seeds we say we grow them. We grow the plant. To grow meaning we plant the plant.

Okay. Now, the words which you are going to learn under that is re-pro-duc-tion. All of you.

Ps Reproduction

T Reproduction. What is now this reproduction? Reproduction is the way that a plant makes a baby. When a plant makes a baby we say that reproduction takes place. Re utlwana (agreed)

Ga semela se dira ngwana, reproduction takes place. (When a plant makes a baby ...)

Reproduction takes place. Okay now let us read our story first.

COMMENTARY: At the beginning of the lesson, Ellah was hurrying the children to get their materials out and get the lesson started. It is possible that she confused the children by making an equation between planting and growing. When it came to introducing the new word <u>reproduction</u> (which was only supposed to be introduced later, according to the materials), she first taught them the pronounciation, and then proceeded

with four explanations about the concept. She quickly translated part of her explanation into Tswana, and then finished her definition with English.

Later in the lesson, when making a cutting, the following interchange takes place. (As a reference point for the reader, the following was the extract from the material that the class was using: *Cut just below the node of the stem. The "node" is the place where the leaves grow out of the stem.)*

T Okay now the next thing after cutting a piece of stem now there is a way we must follow. Now then we cut that ... you see we must cut the stem just above the node. We have a word for that .... called node. All of you.

Ps Node

T Node

Ps Node

T ((To observers) I have forgotten the piece of stick to show them what nodes are.) Okay. Now we have here ... do you see that thickening? Heh?

P Yes

T Do you see that? Heh?

Ps Yes

T Dikukuno tse, wa di bona, di tshwana le sejabana sa ka neh, dijabana tsa setlhare, dikukuno a si di, bona di ntse jang wa di bona, heh? (these protrusions, can you see them, they look like my elbow, right, the elbow of a tree, these protrusions, see how they look). They are the nodes. They are the what?

Ps They are the nodes.

T They are the nodes. Now when you cut your stem you must cut it above the nodes. After that, listen. Now what is a node? The node is the place where the leaves grow out. Look at this one. The leaves are growing out. Okay we will pass it round so that everybody can see it. Leaves grow from the nodes. Here is a leaf starting to grow from the node. Right. That's why we say a node is a place where the leaves start to grow. A node does not grow, a leaf does not grow anywhere. It grows from a node. Can it grow from here? A leaf? Can a leaf grow here? Can it grow from here? Can a leaf grow here?

Ps No

T It must grow on the node.

COMMENTARY: here Ellah is in the middle of demonstrating making a cutting. In fact she has made the cutting that is to be used the night be-

fore, and soaked it, but here she has to show the right place to make it on a stem. Once again she introduces an item - "node" - and gets the pupils to practise it before she explains it. Here the explanation is lengthy, and we get a picturesque and complex explanation in Tswana. It is doubtful whether we would explain to English speaking children that a node is a protrusion that looks like an elbow ... Then Eliah slips into the Note Rhythm method for a moment to get the pupils to repeat what she has just said - "It is that what?" After that she checks that the children have understood that this is the place where growth occurs. From this second extract we can clearly see why the lessons take so long to give. Everything is explained and explained again, with a very careful focus on the comprehension of single items, almost at the expense of the continuity of the process or concept. Learning is almost reduced to a serial accretion of discrete items.

We were very concerned that the lessons took rather longer than we had planned. While we were practising lessons in the teacher training lessons, "dry runs" would take about 20 minutes, sometimes the teachers would take about an hour with their pupils. However, when we had an unexpected chance to work with the pupils ourselves (when a teacher was sent on a course without notifying us) we found that we too were very preoccupied with careful attempts to gain and check comprehension. (Burrough's (1989) commentary on the materials offers constructive suggestions for shortening the material where possible and appropriate.)

The use of an observation schedule as part of the in-school observation provided a useful adjunct to the qualitative information that we gathered there (and which is reported in section 8 below). The results give us two main indications that are complementary: firstly, we saw that the materials, if used as prescribed, had a predictable effect on the classroom interaction. However, materials themselves are not strong enough to override characteristic strategies that teachers adopt as part of teaching new and difficult concepts to children in their second language. Indeed it seems to be the experience elsewhere that there are limits on the change one can expect from teachers. Hacker (ibid), in discussing the low adoption rate of enquiry approach materials of the Austrialian Science Education Project has this to say (p.166):

> It may be hoped that future generations of curriculum developers will feel less constrained by psychological theory and concentrate more on reducing levels of dissonance between the teaching approaches they recommend and the preferred approaches of practicising science teachers. It is clearly naive to believe that materials can be used to dictate approaches actually adopted in the classroom.

CHAPTER FIVE

THE APPRAISAL OF LEARNING OPPORTUNITIES : 1987

Walker (1987) was interested in the question "Do learners learn what teachers teach?" He asked this question in the context of the science lessons observed, and did a particularly complete analysis of one lesson on leaves.

A central problem in classroom research is that no clear relationship has yet been found between teaching and learning other than the informative one that instruction makes a difference, that instruction is better than no instruction. The relationship between the two would therefore seem to be indirect, and therefore indirect means should be used to assess it. As part of the process of inference, Walker aimed to distinguish between (a) what is planned to be taught and (b) what actually gets learned (or "uptake"). He drew up a teacher's planning form, which the teacher filled in before each lesson, and also a Pupil's Uptake Form, constructed and filled in in the vernacular at the end of a lesson.

The first thing the children were asked to do was to tick the ideas that came up in the lesson. Walker had decided what the main concept of the lesson was to be (independently of the teacher), and this appeared as one of the items. Also appearing was the core concept negatively formulated, an item from a previous lesson, and two (sensible) distractors. The second question required the children to identify the core concept from the same list of options. In the first question the children ticked all the options liberally, with Walker's core concept receiving the lowest frequency. In the second question, the core concept fared a little better.

It was concluded that "the teacher in this lesson failed to establish the concept that the syllabus, the textbook, and his own planning required him to". However, this conclusion may be seen as too bold on several grounds. Firstly, the fact that the children took more than forty-five minutes to fill in the apparently simple form and wrote incoherent answers for question one and in the second language section suggests that they may have not fully understood what was expected of them: task familiarity is at issue here.

Secondly, it appears to have been an unwarranted construction on the lesson that there should be <u>one</u> core concept, viz. that leaves produce food for the plant. The textbook refers to the form, colour and function of leaves, and so does the teacher under "main focus of the lesson" on his planning form. If the children, faced with a "test", try to remember everything they learnt in the lesson (and some more general knowledge besides), they might well have been confused by the way the questions and options were phrased.

A more effective way to find out what the children had learned would probably have been to take four or five children out of the class and interview them in the vernacular about what the lesson was about. If they mentioned aspects of shape, function and colour, then one would

have evidence of effective "uptake". The question about uptake is clearly very interesting, but perhaps the exercise could be repeated in a way that makes more sense to the children. When we interviewed children as part of the School-Based Learning Experiences study we found that they were often trusty reporters of what usually went on in their classrooms, and what it was they did and did not understand.

The approach that Walker adopted was derived from thinking in applied linguistics about the relationship between what teachers teach and learners learn. In the more general educational literature, there is a related model, reviewed by Bennett (1987). On this account, the basic assumption of the opportunity to learn model is that there is no basic relationship between teacher behaviour and pupil achievement, since all effects of teaching on learning are mediated by pupil activities; in other words, pupils learning activities are central to their learning.

In the most recent work that Bennett reviewed (ILEA, 1986), the teaching from which the highest pupil achievement is gained was characterised as follows:

- a structured setting where the work was chosen by the teacher;
- where one subject is taught at a time;
- the time spent communicating with the whole class is important, with particular stress on intellectually challenging questions and high expectations;
- where a high level of pupil industry is apparent, with low noise levels and little pupil movement, and
- where teachers keep an adequate record of their pupils' achievement, and involve parents in the education of their children.

Bennett (ibid) notes that the research he reviews does not really address the heart of the matter: that lies in the quality of the learning tasks that the children are engaged in. The quality of the tasks that are assigned must be good, and furthermore, they should match the intellectual abilities of the children.

In the present situation of primary science teaching in black education, of course children do not get tasks in the strong sense of the word. They get highly limited exercises to do - copying classwork notes, and memorising these for regurgitation in tests. While we would concur with Bennett that the nature and the quality of classroom tasks requires further research, our basic orientation on the Threshold Project is that the teacher is the critical mediator. As such the teacher must know and understand the nature of constructive learning tasks, so she can effectively mediate these, whether through materials she herself has been trained on, or later, on materials that she herself designs giving them the required instrinsic structure.

CHAPTER SIX

THE CONCEPT TEST AND OTHER RELATED TESTS: 1987-1988.

6.1. The 1987 research. (6)

A concept test was given to Std 3 pupils to determine what background knowledge they brought with them and what learning gains they had made after the section on plant growth and reproduction had been taught to them. The 1987 research is reported first.

Lefofa School Std 3 children were randomly assigned to two classes, class A and class B. (The research design is reproduced overleaf.) Both classes were pre-tested in their mother-tongue, Setswana, before Phase One started in order to ascertain what concepts the children already had. Class A was taught 20 lessons in English and post-tested in English. Class B was taught in their mother-tongue, Setswana, and were post-tested in Setswana.

Other pre-test data was gathered at Tshimollo and Gamelodi Primary schools in Mamelodi, schools under the administration of the Department of Education and Training. These children are comparable to those in Lefofa Primary, and this data serves as a control on whether pupils under the administration of the Department of Education and Training come to Std 3 science classes with more or less the same background knowledge as do children in Bophuthatswana schools. A post-test was done in St Catherine's convent school in Florida. These children are of the same age but of different socio-economic backgrounds to the children in Lefofa, Tshimollo or Gamelodi. Not all of these children are mother-tongue speakers of English, but they have all had English as their medium of learning from Grade 1. This data served as a comparison for the Tswana post-test results.

The pre- and post-test results within each group can be compared to determine what learning gains they have made, and then the between-group learning gains can also be compared. The important question is whether the pupils learn the concepts the syllabus requires of them, because these concepts are crucial ones on which science work of later years is built.

The concept test was written in English and translated in Tswana and the same test was used as pre- and post-test. It consists of 16 concept areas and a total of 52 answers is required. The test items represent a summary of all the concepts required by the Std 3 General Science syllabus and textbooks, covering concepts such as the structure of plants and seeds, the requirements for germination and life of a plant, the order of growth and development for plants, soil as anchorage and the anchoring function of roots.

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(6) This 1987 research was done before the research that was reported on in Chapter Four; section 6.2 below ties in with the teachers and classrooms described in Chapter Four. Figure 6.1. overleaf refers to the 1987 work.

Pre-test: Setswana	Pre-test: English	Setswana
(i) X=43,2% (ii) X=42,17%	X=40,7%	X=43,9%

CLASS A	CLASS B
20 Lessons : taught and learned in English	20 lessons : taught and learned in Setswana

Post-test: English	Post-test:Setswana	Post-test: English
X=42,3%	X=73,34%	X=77,7%

(1) Ishimollo Primary School
(2) Gamelodi Primary School

CONTROL

Lefofa Primary School

EXPERIMENTAL

St Catherine's Convent

CONTROL

RESEARCH DESIGN FOR SCIENCE CONCEPT TEST:
Figure 6.1

Test items differed widely, viz. reading comprehension items, items which required the child to draw inferences or conclusions, prediction items and items which required the child to circle, draw or compare. All questions, however, could easily be answered if the underlying concept was established.

Special attention was given to language construction. For some concepts, however, more language or more complicated language than we desired was needed to make the question clear. When administering the pre-test all the unusual items were carefully explained in the mother-tongue. The 52 items were split into two parts so that the test would not prove too tiring for the children.

For Class A, we found 1,6% learning gain when we compared the pre-tests of the Lefofa children with the post-tests they had written. The average mark for the pre-tests was 40,7% and the average mark for the post-tests was a disappointing 42,3%. No significant learning gain was made during the 20 lessons on plants. Our global interpretation would be that these children have to channel all their energy into learning the English equivalents for the concepts they already have in their mother-tongue.

For Class B, the learning gain was 29,44%. The Tswana pre-test score was 43,9%, and the post-test average 73,34%. The post-test results show that the demands of the curriculum are clearly not beyond the child in his mother tongue. The fact that these children did nearly as well as the St Catherine's Convent (77%), means that Thabo Manne's teacher-centred teaching style was no deterrent to the children's learning. Having said this, it should be added that this teacher did not use the Rote-Rhythm method to any degree, and furthermore he was teaching in the children's mother-tongue. The problems we have identified may therefore be said to operate negatively in the English as a medium of instruction context.

The control data from the Mamelodi School showed that this randomly selected Department of Education and Training school fared approximately the same as Lefofa. This result fits with our general impression that the good township schools are as good as the good PEUP schools.

Items of the test fall into one of four categories when pre- and post-tests of the Tswana-English design are compared. An item was regarded as problematic if less than half the children had that particular item correct (i.e. less than 27 subjects for the pre-test and less than 29 subjects for the post-test). These four categories are:

a. No problems:

17 of the 52 items posed no problems to the children either in the pre-test (mother-tongue) or post-test (English). These concepts, in other words, were already established when they started the module on plant structure, growth and reproduction.

10 of these 17 items required only a low-level ability to interpret graphic representations of parts of plants and the stages in the growth of a mealie (items 1-4; 30-35), which reduces the significance of this category somewhat.

b. Problem resolved:

More than half the children failed to answer items 16 and 27 correctly in the pre-test, but more than half the children could answer them correctly in the post-test. Taken at face-value then, these two items seem to be instances where real learning has taken place. Let us take a closer look at these two items.

Item 16 is a reading comprehension question as to what living things need to stay alive. In the pre-test, item 16 was a borderline case (46% correctly answered). In the post-test this item was still a borderline case, with 55% of the answers correct. There may not have been a clear learning gain here.

Item 27 asks what the child thinks will happen if we give a seed water and air but no warmth. The children already know that seeds need water and air to germinate when they start the module about plants. The fact that warmth is also needed seems to have been learned. This item could then be regarded as a learning gain. But this learning gain is not very much, as subjects merely broaden a concept they already had, and do not learn a new concept in the process.

c. Problem created:

Three of the items presented no problem to our subjects in the pre-test, yet less than 50% of all subjects taking the post-test answered them correctly.

Item 14 requires the subject to read a piece of text and answer a question. Although neither the language or the concept involved was very complex, the language seems to have been too much for subjects to process when given it in English.

Items 22 and 46 require subjects to circle a pineapple on a mealie plant and draw roots for a cutting respectively. During the pre-test, these tasks needed repeated explanations. They were explained in English by us and a number of times in the vernacular by a teacher of the school.

When administering the post-test, the unusual items were not re-explained. The children were asked whether they understood and remembered, and when this was answered to positively, the answer was taken at face-value, because we expected that they would remember the nature of the task since it seemed so unusual to them during the pre-testing. Cultural norms might have been operating, however, not allowing subjects to admit that they did not remember or understand anymore.

These items then could have become problem items because the children did not understand the task, not necessarily because they had not learnt the concept involved.

d. Problematic item:

The majority of items (30 out of the 52) fall in the last category where less than half the children could answer the item correctly in either the pre- or the post-test. In other words, where the children did not

seem to have these concepts before the teaching or after having been taught for six weeks. For example, most children did not know what happens to the stored food in a cotyledon when a seedling grows before or after they were taught (item 20). (However Tss Rona does not deal explicitly with this concept.)

It seems that our global interpretation of not much actual learning taking place because of the strain of the medium change is probably correct. This concept test is a critical tool in our evaluative kit, and was revised slightly for use in Phase Two of our research. (One sentence was added for clarification, and a picture sequence was changed to obviate any ambiguity.)

6.2 The 1988 research

There was another research design adopted in 1988. We were able to get three measures which would give us a deeper insight into the kind of learning that the children were achieving, namely, a vocabulary test, the concept test, and a teacher-constructed class test.

In the first quarter of 1988, we had three teachers from three different schools in the Moretele Circuit, Temba, who used our specimen materials. The Tswana concept pre-test constituted a base-line from which the teacher would have to work. After this the teachers were trained for eight weeks (four hours on Monday afternoons). When the teachers had finished their 24 lessons, the vocabulary post-test, the concept post-test, and the class test were administered.

The 1988 data are only comparable to the 1987 data for the concept pre-test. Not only did the teachers receive different intervention, in the form of our specimen materials, but they also taught 24, rather than 20 lessons (as did the Phase One teacher). Although the concept test did not deal with anything in the last four lessons, strictly speaking the post-test results should not be compared with the 1987 results.

Another factor which may have affected one of the schools' results, viz St Camillus. The teacher being trained withdrew about 40% of the way through the training course. She found it too much of a strain to participate in the training programme and an even greater strain to be the subject of classroom observation, so she was replaced by a Std 4 teacher who was extremely willing, able and articulate. We feel certain that the children benefitted from this change of teacher.

We devised a simple picture vocabulary-labelling task, which we administered pre- and post-intervention, both in English. We wanted to find out what of the common vocabulary the children had in English to start with, and what they learned. Naturally this test is easier than the concept test, because it does not rely on reading comprehension. We used clear pictures (illustrations from our materials) for the task.

We report the results of the vocabulary test in Figure 6.2 below.

SCHOOL	PRE-TEST /26	POST-TEST /26	GAINS
St Camillus	7,09 27,3 %	17,71 68,1 %	10,62 40,8 %
Selang	9,78 37,6 %	18,28 70,3 %	8,5 32,7 %
Seroto	7,68 29,5 %	17,98 69,2 %	10,3 39,6 %

Figure 6.2. *Pre- and post-test results on vocabulary test*

The pupils started off from quite a low base, which was to be expected, since they had never formally been taught about plant structure in English. However, they generally know the familiar parts of the plant, but could not supply names for the different kinds of roots, nor could they describe the inside structure of the bean and maize seed. They were able to do these much more competently on the completion of the unit. The general level of just under 70% for the post-test was considered satisfactory.

The second results which are of interest are those of the concept test itself. The results are shown at Figure 6.3 below.

SCHOOL	PRE-TEST /52	POST-TEST /52	GAINS
St Camillus	23,54 45,3 %	27,9 53,6 %	4,36 8,4 %
Selang	23,7 45,6 %	27,8 53,5 %	4,1 7,9 %
Seroto	19,2 36,8 %	21,68 41,6 %	2,52 4,8 %

Figure 6.3. *Pre- and post-test scores on the concept test*

There are three major observations to be made here in relation to the concept test. Firstly, it is clear that the English vocabulary, which was markedly lacking in the pre-test, is easier to learn than concepts. This is shown in the lower pre-test scores but bigger gains shown in the vocabulary test. Secondly, it seems to be relatively difficult to make gains on the concept test, after the language medium is changed. However, the interesting question relates to the adequacy and validity of

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the post-test scores. One external criterion of validity which we have is the marks that the pupils got on a common "final test" (7) that the teachers designed. Although moderation of the tests show that the teachers mark more strictly than we have on the project, the marks are generally similar:

St Camillus: 45,2%
Selang : 49 %
Seroto : 46,3%

The results in detail are slightly different from our tests. Selang did the best of the three schools, but they did rather more poorly than they had on the concept test. Surprisingly Seroto did slightly better than St Camillus, but perhaps because of less reading comprehension skill being required, it did better here than on the concept test. It seemed that the Seroto teacher who appeared to perform rather more poorly in classroom evaluation, did indeed inculcate facts in her pupils but only where very little in the way of process skills were required.

In our research in 1987 on cohesion, we found that the Seroto children had a great deal of trouble with English. We discovered that for these children, English is the third language. They belong to a South Ndebele clan which speaks the dialect Pedi, but they have to learn through the medium of Tswana, and later English. The subjective impression in class is that there is very little comprehension in English. Hence we were expecting this school to have the poorest results, both pre- and post-test.

Although there cannot be a direct comparison with the "traditional" teaching as carried out with Tsa Rona the percentage gain is rather more than the 1,8% gained on the Phase One class. However, while we might be gratified at the gains of 4-8%, we are still acutely aware that these children are performing under their conceptual potential, which would be realised in their mother tongue. As will be seen in Chapter Seven, there were shortcomings in the materials themselves, and we had probably expected too much of the teachers. Given these considerations, we have to say that the results were satisfactory. However, with a closer mesh between better English and appropriate Science materials better results should be obtainable in the future.

The girls at St Catherine's convent school, who also used these materials, but in a more informal and unmonitored situation, did rather better on class tests and examinations, getting 82% and 70% respectively. These tests, very similar to the class tests our teachers set, were also largely content- and not process-oriented. Of interest here is the discrepancy between the convent girls' largely activity-based approach to science and the conservative way in which their skills were assessed.

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(7) The common test that was set was content-oriented, and it would have been equally appropriate to test children who had learned through the Rote-Rhythm method on this test. However, for our purposes, we had wanted a teacher-set conventional test that we could use for comparative purposes. It is clear that class evaluation is an issue that has to be addressed simultaneously with innovation in method.

CHAPTER SEVEN

THE SCIENCE PROCESS SKILLS TEST (1987)

When designing our new materials on plants, we had to be sure that the science processes we thought of using were within the potential grasp of the children. Thus we tested science process skills which are implicitly required in the unit under study.

The subjects were 10 girls and 10 boys in Std 3 at St Camillus Catholic school, just west of Temba (Hammanskraal). Although the school is not a so-called model school in the Moretele Circuit, their public examination results for Std 4 are the second best for 41 primary schools in the circuit.

The process skills thought to be achievable by British school children by the fifth year of primary school have been set out by Harlen (1985). These children have language skills which are far in advance of what may be expected from our target group. Hence we present a list that is similar to Harlen's, but modified for the language skills we see as feasible at this stage:

a. Observation
   1. Using the senses to gather information.
   2. Identifying differences between similar object/events.
   3. Identifying similarities between different objects/events.
   4. Recognising order in which sequenced events take place.

b. Interpretation of information
   1. Identifying trends or patterns in information.
   2. Understanding patterns or relations in recorded data.
   3. Using patterns or relations in information, measurements or observation to make predictions.

c. Inference
   1. Putting together information and making deductions.
   2. Suggesting relations to account for the existence of patterns.
   3. Realising that checking an inference requires more information of a different kind.

d. Explanation
   1. Attempting to explain observations or relations in terms of some principle or concept.
   2. Realising that there is some similarity between two situations and applying concepts or knowledge gained in one situation to help understanding or solve a problem in another.

e. Devising investigations
   1. Deciding what equipment, materials etc. are needed for an investigation.
   2. Identifying what is to change or be changed when different observations or measurements are made.
   3. Identifying what variables are to be kept the same for a

fair test.

All the questions that were asked involved the use of pictorial materials accompanied by discussion in the vernacular. Each of the 6 tasks had a number of questions (which were discussed in the vernacular) accompanied by black-and-white or coloured pictures. The process skills covered by the tasks were as follows:

Task 1: Observation of similarities and differences.
(Looking at the picture of a flower and a tree.)
Task 2: Observation of similarities and differences.
(Sorting seven leaves by colour, shape and edge.)
Task 3: Observation: recognising the order in which a sequence of events takes place.
(Sorting eight pictures of the growth of the bean.)
Task 4: Interpretation: understanding pictorial patterns of measurement; also, prediction.
(Predicting and explaining growth point on root.)
Task 5: Prediction/inference. Putting together information and making deductions. Using relations in information, measurements or observations to make predictions.
(Working out the conditions for growth of a plant.)
Task 6: Inference.
(Working out how a cutting grows.)

We had wanted to keep second language interference in these cognitive processes to a minimum, and hence tested the children in their mother tongue. Although the Concept Test we designed was also in the vernacular, it differed from the present test insofar as it also tested the reading comprehension capacities of the children. In both cases we obviated the interference of limited English skills which would have masked true capacity.

We were very pleasantly surprised by how much the children were able to give us in this process skills test. The only item (Task 4) which we definitely suspected as being outside the reach of the children did indeed prove to be so. (On this task the children found it difficult to work out where the greatest growth area on the root would be.) However, poor performance on the Concept test, which was, if anything, easier than the present test, strongly suggests that the children's verbal skills are far superior to their reading comprehension skills at this level. (8)

The second major finding was that the children spoke eloquently in their mother tongue in this one-to-one testing situation. Never have we seen children speak so long and so eloquently in the classroom situation. We know that this is a strong function of the classroom "culture" that prevails, in which the children are called upon to give one word answers, mostly to questions testing their short-term memory for information the

(8) However, our Setswana Reading Comprehension Task entitled "I didn't think of it!" shows that there is nothing wrong with the children's basic reading comprehension.

teacher has just given. It is important that the teachers should be told that the children have a great deal to contribute to the teaching process, and that to listen to the child's process of thinking will help the teacher to know where to lead the class. This is an important principle for practice, for otherwise the teacher may be failing to "match" the learning material to the cognitive capacities of the child.

We are able to confidently conclude that this aspect of the Std 3 science syllabus is within the grasp of the children, and that, by-and-large, they can exercise process skills appropriate to the concepts. However, we cannot thereby conclude that the children would be able to deal with the concepts and skills intrinsic to the rest of the syllabus. For example, the concepts of heat and air are more abstract than those we have dealt with here, and we do not know whether children will be able to manipulate them. However, Van Rooyen (Disparities Final Report, 1989) has pointed out on the basis of testing text comprehensibility - biology vs physical science - that contrary to what she expected, the physical science text was not less comprehensible, and she attributed this to the very concrete nature the demonstrations of the properties of air took. Kenyon (pers. comm.) has also questioned whether the contrast should not be relevant/irrelevant to the child's immediate personal concerns, rather than concrete/abstract.

There is an unhappy codicil to the generally positive picture that has been presented. The children are able to deal with what we presented to them - but what would the picture have been like if we had tested the children after they had learned this section of the syllabus in English? It is most unlikely that the children could have given us so rich a picture, because their productive oral skills are so very weak (as we describe in the English languages skills evaluation final report). The only science that they would have practised in English would have been their one word answers we were referring to above. They would certainly not have any English that would give evidence of the richness of their private "theories" that enchanted us. Here we have a real challenge to the teacher: she must be able to elicit what the children know, in the vernacular, and then give them sufficient English to act as a vehicle for their ideas. It is difficult to see how this will be accomplished given the classroom interaction styles that prevail, as well as the physical constraints of limited class time and large numbers.

We made a number of recommendations from this study.

Firstly, that some attention be paid to the finding that the children are able to deal better with higher order concepts orally rather than in written form, in the mother tongue. This finding may be of academic interest only because the vernacular is not the medium of instruction. However, attention should be given to their writing skills in the mother tongue (cf. the School-Based Learning Experiences Final report for further discussion on this matter).

Secondly, that teachers should reconsider their accepted practice of ignoring the contribution pupils have to make by virtue of their real world experience. The child's perceptions should be woven into the fabric of the lesson in a way that will make the material more meaningful to the child, and more closely matched to the level of his perceptions.

To do this will require a major reorientation on the part of the teacher, because she is the principal orchestrator of the lesson, and the one who controls the rate of outflow of knowledge in the public domain (cf. the School-Based Learning Experiences Final Report for further discussion).

Thirdly, that close attention be paid to the productive use of the vernacular in the early years of English as medium of learning. By allowing the child to express his perceptions in the vernacular and by expressing the same in English, the teacher will be providing the child with a vehicle for expressing in English his own concerns in addition to using the language of the textbook and teacher.

Fourthly, that teachers should facilitate the use of process skills as far as possible in the science and other classrooms. We have evidence that the child can spontaneously exercise his process skills in a situation which is conducive to doing so. However, we do not know whether higher order process skills will develop if the lower order skills that can be exercised at this level are not nurtured. We are aware of the fact that teachers would have to be trained in a different style of classroom interaction.

CHAPTER EIGHT

THE DEVELOPMENT AND EVALUATION OF SCIENCE MATERIALS.

Because the development of examples for new materials is such a critical aspect of our project (if they are viable, then we have our "feasible" profile we are seeking, as well as concrete exemplars to give to curriculum planners and textbook writers), it was addressed over a number of months in project seminars. When we had negotiated what we each thought should be in the materials, we jointly designed two lessons, and then divided the remainder amongst ourselves. Because of the postponement of Phase One, we were able to revise and add to the materials towards the end of 1987.

The momentum for change to a transitional model is carried by the pupil materials and teacher handbook, so we should turn to an examination of these now. We should like to stress that the materials we designed do not, in our estimation, require special training for teachers to be able to use them. The reason why we included in-service training was because we wanted to work with teachers closely to assess their response to what are really rather novel - but we stress, not intrinsically difficult - materials.

Before details of the approach are laid out, it would help the reader to have a comparative sample of expository text from the text our subjects generally use (i.e. Tsa Rona) as well as our own. These can be seen at Figure 8.1. In our materials the topic is introduced in broad terms in Lesson One in Setswana.

Figure 8.1

PLANTS AND MAN (TSA RONA MATERIALS)

In this chapter we shall investigate some of the plants around our school.
We shall try to identify plants in our environment.
We shall see what plants look like and what functions the various parts of the plants must perform.

A. The structure of plants.
In this section we shall study the general structure of plants.

Activities (field work)

1. There are many plants growing around your school.
Some are useful but there are also some that are unwanted.
Look at the plants carefully.
Notice that they consist of various parts.
These parts have different colours.
They also have different shapes.
Each part has a special function to perform.

LESSON TWO: THE STRUCTURE AND FUNCTION OF THE PARTS OF PLANTS

READ THIS

All plants have roots, a stem or many stems, leaves, flowers or fruits and seeds. We are going to look at these parts of the plant.

1. Roots

The roots of the plant are always under the ground. They grow downwards into the soil.

Roots have two functions. Firstly, roots keep the plant in the ground. We say that roots anchor the plant in the ground. Secondly, roots take in water and salts from the soil.

There are two different kinds of roots. You will learn more about this later.

2. Stems

All stems grow upwards towards the light. They do not grow down into the soil like roots.

How many stems does a plant have?

A plant can have _____ or _____ stems.

Our model of science learning is transitional and our text is too. Because Std 3 is the time for the introduction of a number of expository content subject textbooks for the majority of children, we tried to train learners into the use of such texts. We did this by using symbols for components such as READ THIS, HOMEWORK and LANGUAGE etc. However, in the classroom context, we did not see the teachers drawing the children's attention to these per se, although the children found their way around the books easily.

Our text is also transitional insofar as it has narrative and expository components. For example, our first lesson is a Setswana story, followed by the recapitulation of the same components in expository English. (We had originally designed a simple repetitive story in English, and then tried this story on children at the end of Std 2; when it became clear that they could not comprehend it at all well - and the length of the text may have been at issue here - we decided that the story should go into the vernacular. By using the mother tongue, we could be certain

that all the basic concepts contained in the lesson would be thoroughly dealt with.)

We have attempted to present the contents of the module at a viable language level. The vocabulary was carefully selected, the complexity of syntax controlled, and the discourse is well-connected. We would like to be able to claim that, if the children cannot use this language, then they should not be dealing with these concepts in English yet, since there are intrinsic demands that the concepts make on the linguistic complexity. (9) However, we are pleased to report that in a c-text comparative study of our materials versus seven prescribed textbooks, ours rated the easiest (cf. the Disparities Analysis Final Report). This does not however mean that it was fully comprehensible. For example, we noted that the children could not do cloze passages in the text per se (the passages were on an experiment method that they had just seen.) Hence in our commentary that appears as a companion to this report, we recommend that children get more cues in similar exercies. If we were to raise the level of the children's English competence to what we would consider in our terms a "feasible" level, then this text should not present anything of a problem; however, at the moment, ideally, children should probably work in even simpler workbooks, with less material. To do this does not mean that the syllabus would have to be reduced, but rather, reinterpreted in terms of what is expected in terms of typical tasks.

The illustrations, with one exception are functional and not decorative. They are referred to explicitly in the text as Picture 1 etc., and so they should provide an aid to the comprehension of the language. We felt it was important to make the labels explicitly related to the text, because we have research data (Van Rooyen, 1987) that children generally do not understand the relationship between the picture and the text, and they don't know what fig's are either! The children participate in completing some of the pictures, and make their own in other cases.

We intended the materials to enhance different language skills: firstly, the children are regularly asked to write down words and sentences in their workbooks. The LANGUAGE FOCUS exercises (which sometimes appeared as HOMEWORK) are intended to help children with English across-the-curriculum related to the current topic. The teachers were less excited about the LANGUAGE FOCUS exercises than we were: while they saw that they did have a bearing on the topic, they were inclined to down-grade their importance, because they found it was difficult to get through all the materials in the time allowed. The convent teacher who trialled the materials for us said that these exercises were rather too easy for her mother tongue children, but felt certain that they did benefit her ESL children. In retrospect, we would consider the use of such self-conscious language focus exercises to perhaps be ill-advised, except where careful contrasts between lexical items need to be made; however, these explanations can constitute part of the text per se.

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(9) We know from individual testing in the vernacular that the concepts and process skills inherent in this part of the syllabus are well within the capability of the children cf. Chapter 7 above.

We also tried to promote interactional skills in the playing of two games. The games were designed for whole class use, as well as small groups afterwards, and we were rather disappointed that the teachers only used them in the first way. It is not clear why they did not encourage the children to play the games on their own afterwards. Perhaps it was because of time pressure, as we know that our subjects have been trained in self-reliant games in the lower primary. Once again there emerged a difference between the convent and PEUP children. The convent children learned the two games in class, and then demanded to be allowed to play them at every available opportunity. They did this when they had finished lessons early, after school, and they even came early to school for this purpose! It may be that the PEUP teachers were also unduly careful about monitoring the use of what would be to them valuable resources.

There was a very self-conscious attempt on our part to mould certain questions the teacher asked the children. The so-called KEY QUESTIONS appeared both in the pupils' and teachers' books, so that everybody would know they should be asked. These key questions involved the use of process skills, and also checked background and learned knowledge, and constituted the sine qua non of what we assumed a teacher-directed discovery method should contain. Our observations revealed that the questions were all dealt with in the class, and we were really gratified to find one teacher making up many of her own questions spontaneously, thereby expanding our efforts.

The materials also provided for the possibility of across the curriculum work, with obvious reference to the English teacher. However, these possibilities were not taken up by the teachers during the course of the research. We also built in a carefully balanced use of the mother tongue, such as in the introduction of new vocabulary and difficult concepts. We allowed for the possibility that children's novel ideas should be expressed in the mother tongue first, and then immediately translated by the teacher. In the event, however, while the teachers would sometimes use the vernacular (and not always at the same points in the lesson), instances of the pupils being allowed to use the vernacular were very rare. This accords with the policy of the Bophuthatswana PEUP which tried to minimise the use of the vernacular immediately in Std 3. It is difficult to lay down any explicit guidelines for the use of the mother tongue, because bilingual speakers are likely to anticipate learners' problems in understanding most clearly (cf. also the remarks about the use of Tswana in Chapter 4 above).

The materials are intended to promote a positive attitude towards science. The children should be encouraged to be curious, acquire respect for evidence, and go some way towards becoming able to critically reflect. It is not clear to what extent we achieved these ambitious aims, as the weight of innovation meant that we were monitoring overt behaviour, viz. teachers' classroom behaviour, rather than subtle attitudinal changes.

Finally, we look in more general terms at the use of the specimen materials. We found that it was difficult to estimate accurately how long each experimental lesson would take to trial. The three teachers we worked with were very co-operative and tried to keep up to schedule with

the lessons. This meant that they made inroads into time from other subjects. Naturally this could not occur in a routine use of the materials. The teachers suggested to us that we could cut down on the repetitiveness of the materials. We had explicitly duplicated most of the information in an attempt to impress on the teachers that they did not have to drill their children. However, the one teacher who had the weakest children (Salome) drilled them in any case and perhaps our well-intentioned duplication simply compounded a very deep phenomenon. We found in our later ethnographic study (cf. the School-Based Learning Experiences Final Report) that Salome held tenaciously to the belief that children learn best by drill and repetition - especially, she said, for those that could not read! (Here she was was referring to Std 3 children.) For us this experience was a clear demonstration that we would have to be very clear about the teacher's implicit "rules for being" before we could negotiate fundamental changes in teaching style. We have also discussed the intrinsic tendency towards using more time in the drive towards English comprehension which we discerned from the first micro-analysis of the classroom transcripts.

Time was not a problem with the convent children, and in many cases the teacher finished work in 75% of the estimated time. Informal observation indicates that the pace of classroom management and interaction is so conspicuously faster than with the PEUP, that this must be the cause. The fact that all the convent children are at least superficially fluent in English naturally allows for the interaction to be speeded up.

The teachers explained to us their experience of the change to our transitional method. They said that the use of workbooks took away some of the absolute control they had. Usually the children regarded teachers as the sole repository of knowledge, who would interpret the textbook in the form of notes for them. The normal pattern is for the teachers to teach orally, and then give the children a summary of what the teachers take to be important in the textbook. Now the teachers and children were both actively engaged in comprehending a text, which took away some of the authority from the teacher.

We also discovered that it was quite difficult for the teacher to use a teacher's and pupil's book simultaneously. There appeared to be some difficulty with envisioning a lesson from the teacher's book, but when the teachers annotated the pupil's book they found that they could happily conduct a lesson. It may be that future work could productively change the format of the teacher's book, so that it contains all the pupil material with instructions, observations and objectives on the facing page. Kenyon (pers. comm.) has suggested that teacher-referring information could perhaps be printed in a different colour over the dominant text.

There were multiple facets in our science research, as I indicated at the beginning of this report. We can say in general terms that our materials address current issues in text usability, and could well be useful to potential users. However, the acceptance of consumable workbooks for pupils is a policy decision for the various education departments to take. What is at issue here is the trade-off of textbooks plus exercise books against lower quality (production) workbooks.

Further detailed commentary about the use and appropriacy of the materials may be found in the commentary written by Burroughs (referred to in Chapter 8), and an interesting comparison may be made between the official project specimen materials, and a small sample of rather more simplified alternative materials she devised for us. (These however, have not been empirically trialled.)

Since we completed this science module research, we have had further opportunity to consider the role of media in the classroom. We are convinced with O'Malley (ibid) that general science is a subject that can well facilitate language learning and development if it is experientially-based. However, for it to be experientially based requires the expert management of aids and resources. So for example, we would consider it necessary that a kit be designed for primary science (Std 2 to Std 5) that would allow the teacher to carry out all the demonstrations or experiments in some form. We would also be in favour of nothing less than good quality wall charts, illustrating the major concepts and processes in the syllabus: the motivation for this is that the child can learn to makes complex associations between related concepts without having to have it all spelt out explicitly in complex language. To this we would add the management of a more general resource, the classroom library corner (or trolley)! Here the child should be able to find similar information in different sources, and learn how to use information or fact books. (This last resource has been discussed as a major recommendation of the English Language Skills Evaluation Final Report.)

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

This science research conducted on the Threshold Project was an attempt to integrate our findings and best intuitions in a concrete way. We felt that this modular approach would help to guide our thinking, as well as form a basis for evaluating other thinking in the field of bilingual education. As a consequence, we examined the learning about, and teaching of, the notions of the nature of plants, their structure, reproduction and growth from as many angles as possible, and this has engendered what we hope is possibly the most understandable account of the broad ranging concerns of our project.

Although the recommendations arising from our research are summarised at the most general level in the Main Consolidated Report of the project, more specific conclusions and recommendations that have arisen in the course of this report are summarised below.

a. Looking at the relationship between the learning of science, and the development of thinking skills, there are some recent contributions that have been made from cognitive theory. These contributions come from the areas of information processing theory, specifically the notions of maturationally increasing information processing capacity, and metacognition or executive control; contributions also come from research on alternative or intuitive conceptions of scientific phenomena. Other project final reports (School-Based Learning Experiences, and Reasoning Skills and the Curriculum) make extensive reference to the first two contributions, but the field of alternative conceptions could well benefit from specific attention and further research in the South African context. Questions of interest would include both what teachers and children make of the science concepts that they are expected to learn, and whether the teachers are capable of drawing their children's concepts through to more orthodox notions. The question is asked very seriously, because it may be that the teachers do not think that what is in their pupils' heads is of much consequence, and therefore the usefulness of the whole approach would be likely to be undermined in practice.

b. The question of an appropriate teaching method was discussed at length in the Threshold Project. It seemed very important to us to discover what the characteristics are of the current situation (rather than simply assuming the accuracy of the folk-view of the prevalence rote learning), and we were able to discern that a particular kind of child-centredness may obtain in the lower primary, but that because of the constraints of language and novel concepts, there is a reversion to rote receptive learning in the higher primary, that is, from Std 3 onwards. We have argued, bearing in mind the constraints, for the development of a teacher-centred enquiry approach, or what we have called a transitional model. This model was explicated in our materials, but we recommend that the central notions, i.e. that the teacher retains explicit control in the classroom situation, but uses challenging questions, could well be used in the development of materials from other subjects.

c. When we piloted our specimen materials, along with inservice teacher training, we found that teachers did not simply become automata, blindly following all the explicit directions in the materials. They each interpreted the materials in their own way, and superimposed their own idiosyncratic styles on the material. However, further distinctive patterns of interaction emerged that seemed us to be culturally constrained. There seems to be a very strong need for research that will get to the deeper structures of motivations and intentions underlying patterns of classroom interaction. Once these have been clearly identified and described, "transitional" patterns can be negotiated in an experimental way with teachers. These transitional patterns would be more consonant (than current patterns are) with generating integrative knowledge, knowledge that children fully comprehend and manipulate.

d. The empirical results that we obtained on our Setswana and English tests were most revealing. In summary:

(i) The children already knew a great deal in their mother tongue about the topic of plants before they began instruction.
(ii) After being taught in the conventional way in English, they were able to demonstrate no real learning gains afterwards in English.
(iii) After being taught in the conventional way in Setswana they were able to demonstrate large learning gains afterwards in Setswana.
(iv) After being taught in the new "transitional way" in English, they were able to demonstrate some learning gains in English afterwards. (Unfortunately, a direct comparison between (ii) and (iv) is not possible.)

We were able to conclude that in its present form, the policy of effecting a complete transition to English in Std 3 is clearly hindering the measurable learning of the children. The small scale intervention of 24 lessons was sufficient to help the teachers towards some change in their teaching style, but it did not give us a clear indication of how much further intervention would be required before we could reach satisfactory levels of performance with the children. This complex question is discussed at length in the project main report.

e. The science process skills research (conducted in Setswana) gave us a clear indication that childen were able to deal with many process skills appropriate to the curriculum, if they were put in a conducive environment, in other words, tested in a leisurely manner by a supportive tester who encouraged the children to work things out for themselves. The positive implication of this particular study was how capable the children were revealed as being: but this consideration is rapidly counterbalanced by the consideration of the children's typical learning environment. The nature of this environment, and the ways in which it might be changed, is addressed in every one of the seven final reports of this project.

f. Since this research was carried out, there has been a major initiative in the Department of Education and Training towards revising the junior primary curriculum. The syllabi that have been developed have to be in line with the core curriculum of the Department of Na-

tional Education. The core curriculum has general science starting as a subject in Std 2. Since I have been privileged to have been part of this initiative, I have been able to help strengthen the Environmental Studies syllabus, which has been woefully inadequate up to now in laying the conceptual foundations for later learning. What is now on the drawing board will hopefully make for a more coherent learning progression from the junior through to the senior primary phase; however, the implementation of a new curriculum including the changing of attitudes and styles of classroom management, as well as the provision of appropriate material resources will be a major challenge for the next decade.

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ADDENDUM

COST: CLASSROOM OBSERVATION OF SCIENCE TEACHING

School: .....

Teacher: .....

Observer: .....

Date: .....

Topic: .....

Standard: .....

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TEACHER-CENTERED	1.	TEACHER: makes statement of fact and principle															
	2.	TEACHER: asks pupils to recall fact and principle															
	3.	TEACHER: asks pupils to recall by regressing															
	4.	PUPIL: recalls statement of fact or principle (E)															
	5.	CLASS: recalls statement of fact or principle (E)															
	6.	PUPIL(S): repeat statement of fact or principle (P/C)															
	7.	TEACHER: translates Tswana statement into English															
	8.	TEACHER: repeats statement															
	9.	TEACHER: asks pupils for English translation															
	10.	PUPILS: attention ensured (T/P)															
	11.	PUPIL: drill answer (T/P)															
	12.	CLASS: drill answer (T/C)															
	13.	TEACHER: rewards accurate recall															
	14.	TEACHER: corrects pupil answer															
	15.	TEACHER: makes statement of problems															
	16.	TEACHER: makes statement of hypothesis															
	17.	TEACHER: makes statement of exp procedure															
	18.	TEACHER: directs pupils to self-evident activity															
	19.	PUPILS: involved in self-evident activity (eg copying)															
PROCESS-THINKING SKILLS	1.	TEACHER: asks pupil to support belief with data															
	2.	TEACHER: asks pupil for novel examples															
	3.	TEACHER: asks pupil for counter examples															
	4.	TEACHER: asks pupil about viability of examples															
	5.	TEACHER: looking at alternatives (material/procedure)															
	6.	TEACHER: directs pupils towards practical crit. activity															
	7.	TEACHER: asks the pupils to make direct observations															
	8.	TEACHER: asks the pupils (15) for interpretation															
	9.	TEACHER: asks the pupils (16) for inference															
	10.	TEACHER: asks the pupils (17) application of fair test															
	11.	TEACHER: asks the pupils to make predictions															
	12.	TEACHER: asks the pupils (19) to give explanations															
	13.	PUPILS: use the senses to gather information															
	14.	PUPILS: identify differences/similarities															
	15.	PUPILS: interpreting of observed or recorded data															
	16.	PUPILS: making inferences from observations or data															
	17.	PUPILS: applying facts or principles to problem-solving															
	18.	PUPILS: trying to explain a phenomenon (analysis)															
	19.	PUPILS: ask questions for information															
	20.	PUPILS: ask questions for clarification															
	21.	PUPILS: offers clarification															
PUPIL GROUP BEHAVIOUR	1.	PUPILS: seek guidance from teacher on materials etc.															
	2.	PUPILS: report or explain actions to teacher.															
	3.	PUPILS: organising task co-operatively: Tswana															
	4.	PUPILS: organising group co-operatively: English															
	5.	PUPILS: talk off the topic															
	6.	PUPILS: work independently in group situation															
	7.	PUPILS: talk about the task: Tswana															
	8.	PUPILS: talk about the task: English															
	9.	PUPILS: maintain focus of discussion															

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